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Composition of airborne particulate matter in the industrial area versus mountain area☆

Barbora Sýkorová*, Marek Kucbel, Konstantin Raclavský

VŠB — Technical University of Ostrava, ENET Centre, 17. listopadu 15, 708 33 Ostrava, Czech Republic

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Summary The paper deals with research of air pollution in two different locations on the Moravian-Silesian Region, Czech Republic. These are the sites Ostrava-Radvanice, which is located in the area affected by the industry and Ostravice in the mountains (without significant effect of the industry). The dust particles collected at these locations were subjected to a wide range of analyses. The mass concentration, the mass-size distribution, mineralogical composition, the concentration of PAHs (polycyclic aromatic hydrocarbons), and the concentrations of selected metals (Cd, Pb, Zn, Fe, Mn, As, Ni, Co, and Cr) were observed at the particulate matter.

Introduction

Dust particles in the atmosphere can have an important influence on human health. The extent of their influence is connected not only with particle size distribution of PM (particulate matter) but also with the ability to absorb toxic and carcinogenic compounds (Chung et al., 2008). PM can be divided according to the size into super coarse (>10 μm), coarse (2.5—10 μm), belonging to the accumulation mode (0.1—2.5 μm), Aitken mode — ultrafine (10—100 nm) and nucleation mode (15—40 nm) (Hsieh et al., 2009). The coarse particles are produced mainly by resuspension of dust, demolition and construction works, combustion in local heaters and biogenic sources. Ultrafine particles originate mostly in combustion, high-temperature processes and atmospheric reactions (Amann et al., 2006).

PM is partly formed by minerals with different origin. Quartz, albite, orthoclase, microcline, muscovite and chlorite belong among common resuspended minerals (Amato et al., 2011). Secondary minerals form particles originated in the atmosphere by physical and chemical reactions (gypsum, boussingaultite, sal ammoniac, halite, and lecontite) (Song et al., 2014). Particles from metallurgy contain minerals formed during metallurgical processes and minerals used as input raw materials for metallurgical processes (hematite, magnetite, or maghemite), and components from metallurgical production (graphite, akermanite, mayenite, spinel) (Journet et al., 2014). Carbonates (calcite and magnesite)

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* Corresponding author.
E-mail address: barbora.sykorova@vsb.cz (B. Sýkorová).

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can be components of construction materials or can be released during dosing of limestone into blast furnaces, or can be part of resuspension.

PM can also contain considerable amounts of PAHs (polycyclic aromatic hydrocarbons) — organic compound formed by two or more aromatic rings (Lee and Van Tuan, 2010). PAHs originate mostly during carbonization and incomplete combustion of organic materials (Masih et al., 2012). Combustion of coal represents a source of anthracene, fluoranthene, pyrene, benzo[a]anthracene, chrysene and benzo[k]fluoranthene. Coke ovens produce anthracene, phenanthrene, benzo[a]pyrene and benzo[g,h,i]perylene. Waste incinerators produce pyrene, in lesser quantities also phenanthrene and fluoranthene. Industrial incinerators produce indeno[1,2,3-cd]pyrene and chrysene. Wood combustion is a source of PAHs — anthracene, phenanthrene, fluoranthene and pyrene. Petrol engines release above all benzo[g,h,i]perylene, benzo[a]pyrene and benzo[a,h]anthracene. Diesel engines produce benzo[b]fluoranthene and benzo[k]fluoranthene (Ravindra et al., 2008).

Metals are present in trace concentrations in fossil fuels and biomass and they also can be present in PM. Combustion and industrial processes can be therefore source of these metals in the atmosphere (Smeets et al., 2010). Metals V, Pb, Fe, Cr, Co, Mo, Ni, Cd, As, Sb, and Zn are produced mostly by industry. On the other hand, vehicle traffic produces mostly V, Fe, Pb, Zn, Cd, Mn, Ba, Sr, Al, U, Th, Zr, Cs, Rb, Sb, Sn, and Cu. Combustion of fossil fuels produces mostly V, As, Cu, Co, Mo, Ni, Sb, Cr, Fe, Mn, and Sn (Moreno et al., 2006).

This article is focused on evaluation of dust particles at the two different localities situated in the industrial and mountain parts of the Moravian-Silesian Region during various seasons of the year. Its aim is to find and discuss the possible differences in concentration and particle size distribution of PM or chemical and mineralogical composition of particles.

Material and methods

The monitored sites are located in the Moravian-Silesian Region in the northeast part of the Czech Republic. Neighbours are Slovakia to the southeast and Poland to the north and east. The dominant sectors of industrial activity are metallurgy, hard coal exploitation, energy industry, and chemical industry. Dust particles in the atmosphere were sampled at the selected localities during 2013—2014. Following determinations were performed: mass concentration, particle size distribution of PM ($ELPI^+$ electric low-pressure cascade impactor), mineralogical composition of the total dust deposition (X-ray diffraction), concentrations of PAHs (high-volume sampler, analysis by HPLC-PDA according to ISO 11338-2), and heavy metals (high-volume sampler, decomposition in a mixture of acids in microwave oven, analysis by ICP emission spectroscopy). The locality Ostrava-Radvanice represents a typical area influenced by industrial activity, while the locality Ostravice represents a background, mountain region without direct influence of industrial activity (Fig. 1).

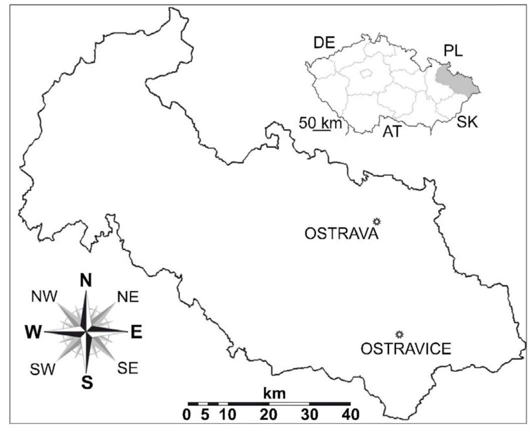

Figure 1 Location of sampling sites in the Moravian-Silesian Region.

Results and discussion

The total concentration of dust particles (PM_{10}) during summer at the locality Ostravice was 15.2 $\mu g/m^3$, at Ostrava-Radvanice was 11.5 $\mu g/m^3$, during transitional period at Ostravice was 17.7 $\mu g/m^3$, at Ostrava-Radvanice was 15.5 $\mu g/m^3$, during winter at Ostravice was 24.4 $\mu g/m^3$, and at Ostrava-Radvanice was 30.2 $\mu g/m^3$.

Fig. 2 and Fig. 3 illustrate particle size distribution of PM. Both localities have multimodal distribution of weight concentrations of PM (without conspicuous peak) during summer. During transitional period, both localities can be observed with bimodal distribution of weight concentrations of PM with main peak in the range from 0.156 μm to 0.614 μm (54% for Ostravice and 50% for Ostrava-Radvanice) and the second less important peak which is represented by coarse particles (11% for Ostravice and 14% for Ostrava-Radvanice). Both localities have identical

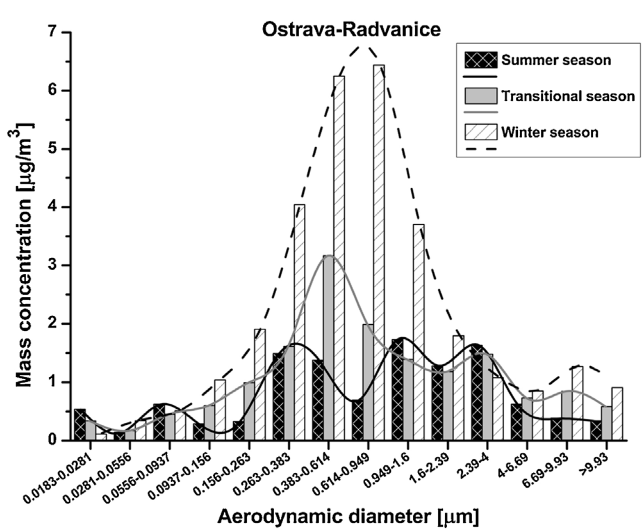

Figure 2 Concentration of particles in particle size classes, Ostrava-Radvanice.

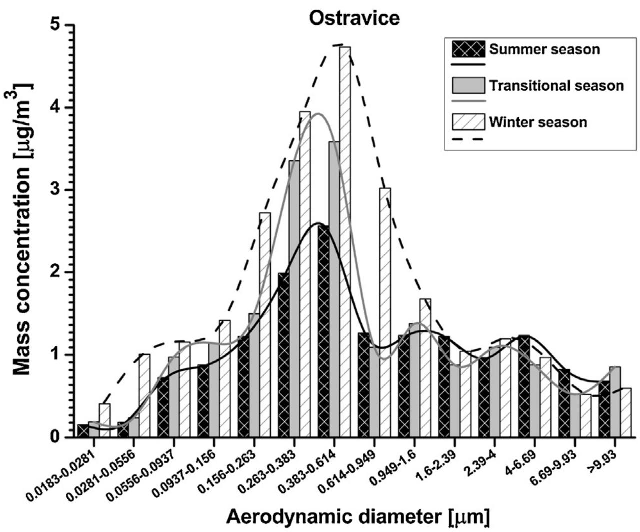

Figure 3 Concentration of particles in particle size classes, Ostravice.

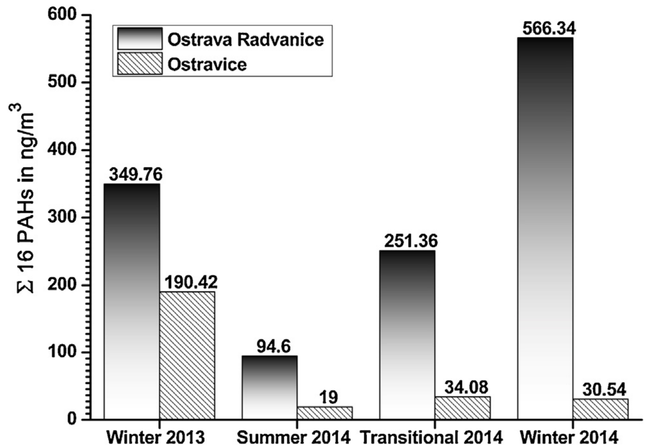

Figure 5 Total concentrations of PAHs.

unimodal distribution of weight concentrations of PM (55% of PM for Ostravice and 68% of PM for Ostrava-Radvanice is concentrated in the interval from 0.263 μm to 0.949 μm).

Fig. 4 shows mineralogical composition of the total dust deposition at the monitored localities. The results are related to the crystalline phases in the sample. The locality Ostrava-Radvanice is strongly influenced by metallurgical activity during entire monitored period (content of hematite higher than 25.9%). Hematite was also determined at Ostravice, during winter 2013 in concentration of 0.35% and during winter 2014 in concentration of 2.07%. The locality Ostravice is also influenced partly by metallurgical industry (Ostrava metallurgy × Trinec metallurgy). On the other hand, the locality Ostravice has higher percentage of resuspended particles (more than 51.1%). The content of secondary minerals is at both localities higher during winter than during summer (2.1—3.4 times).

The highest concentration of Σ_{16} PAHs (16 priority PAHs according to U.S. EPA) was measured during winter 2014 at Ostrava-Radvanice (566 ng/m^3) and the lowest concentration was determined in summer 2014 at Ostravice (19 ng/m^3). Concentrations of Σ_{16} PAHs are at Ostrava-Radvanice from 1.8 to 18.5 times higher than those at Ostravice (Fig. 5). Concentrations of benzo[a]pyrene at Ostrava-Radvanice range from 3.89 ng/m^3 to 21.78 ng/m^3, and at Ostravice from 0.25 ng/m^3 to 5.64 ng/m^3. Concentrations of phenanthrene at Ostrava-Radvanice vary from 21.1 ng/m^3 to 140.9 ng/m^3 and at Ostravice from 8.34 ng/m^3 to 58.7 ng/m^3.

Percentages of metals in the sum of all analysed metals are displayed in Fig. 6 and Fig. 7. Fe has the highest percentage in the sum of heavy metals (86—93%). Zn had the highest concentration (10%) during winter at Ostrava-Radvanice and Mn had the highest concentration at Ostravice during summer (3%). Metals like Pb (Ostravice, summer) or As (Ostravice, winter) formed approximately 1%. Metals Pb (Ostrava-Radvanice, winter and summer), Cu (Ostrava-Radvanice, summer), Cr and Cu (Ostravice, summer and winter) were represented in the range from 0.5% to 1%. Percentages of all other metals at both localities were lower than 0.5%.

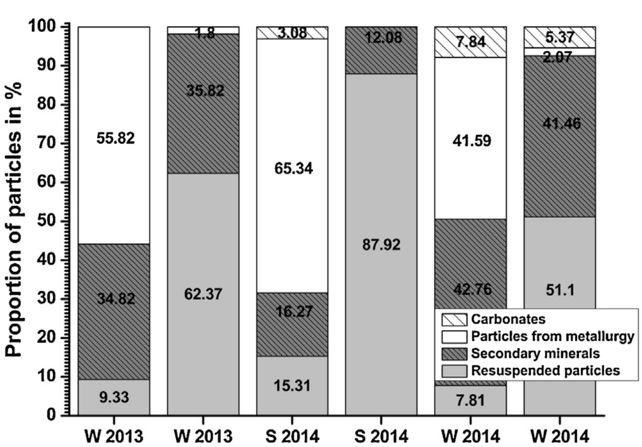

Figure 4 Mineralogical composition of dust deposition.

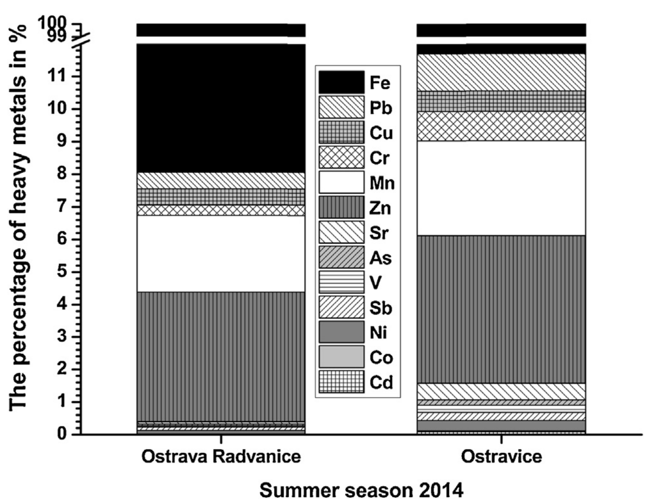

Figure 6 Percentages of metals in the sum of metals, summer season.

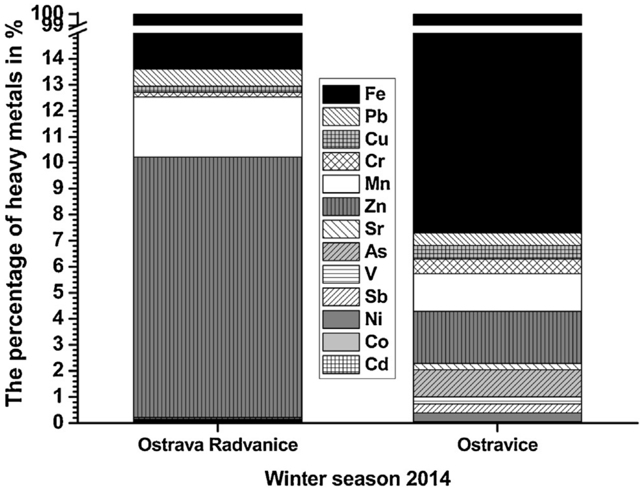

Figure 7 Percentages of metals in the sum of metals, winter season.

Conclusion

From the point of the total concentrations of PM and their weight distribution in particle size classes, both localities have the same character. A study of chemical and mineralogical composition is important for determination of the origin of dust particles. Hematite that has source in metallurgical industry was identified in samples of total dust deposition from both localities. A piedmont area of Ostravice is also influenced partly by long-range transport of PM particles originated in metallurgical industry. Significantly increased concentrations of Σ_{16} PAHs were measured during all sampling periods at Ostrava-Radvanice (1.8—18.5 times higher than those measured at Ostravice). Concentrations of benzo[a]pyrene, mostly originating from petrol engines and coke production, are at Ostrava-Radvanice 2.1—71.3 times higher than at Ostravice. Concentrations of phenathrene which is produced mostly during coke production and combustion of coal and wood are at Ostrava-Radvanice 1.4—13.2 times higher than at Ostravice. Similar trend was also observed for all remaining PAHs. Among metals, Fe has the highest percentage (in the range from 86% to 93%) at both monitored localities. Increased concentrations of Zn at Ostrava-Radvanice can be attributed to the industry; on the other hand, the increased concentrations of Sr, Mn, and Pb at Ostravice during summer are probably connected with vehicle traffic and the increased percentage of As at Ostravice during winter is related to the combustion of fossil fuels (mainly brown coal/lignite) in local heating.

Conflict of interest

The authors declare that there is no conflict of interest.

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